Adaptive Protection in Medium Voltage Maritime Applications

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Adaptive Protection in Medium Voltage Maritime Applications

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DEIF
-power in control

- Description of maritime applications
- Specific challenges in maritime sector
- Typical network topologies
- Protection principles
- Conclusion and future work

- **Description of maritime applications**
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Description of maritime applications

- Marine and offshore applications (ships, sea platforms, oil-gas installations) are islanded power systems that need to fulfill the requirements of the classification societies (LR, BV, DNV&GL, ABS, …)

			
Bourbon Pearl Class: DNV Length: 80.3 m Gross tonnage: 4602 t Accommodation: 75 persons Main generator: 4 x 1.825 MW (440 V) Emergency generator: 1 x 0.25 MW (440 V) Main propulsion: 2 x 2.5 MW azimuth thrusters Bow thrusters: 2 x 0.883 MW + 1 x 0.883 MW Stern thrusters: not available	**Kommandor 3000** Class: LR Length: 118.4 m Gross tonnage: 7731 t Accommodation: 73 persons Main generator: 8 x 1.16 MW (8 x 1.524 MVA) Emergency generator: 1 x 0.313 MW (1 x 0.375 MVA) Main propulsion: 2 x 1.4 MW azimuth thrusters Bow thrusters: 2 x 1.041 MW + 1 x 0.836 MW Stern thrusters: 1 x 1.55 MW	**Far Searcher/Far Serenade** Class: DNV GL Length: 92.9 m Gross tonnage: 4755/5206 t Accommodation: 25 persons Main generator: 4 x 1.74 MW Emergency generator: not available Main propulsion: 2 x 0.895 MW Bow thrusters: 1 x 0.895 MW Stern thrusters: not available	**Rockwater 2** Class: LR Length: 118.6 m Gross tonnage: 5991 t Accommodation: 106 persons Main generator: 5 x 1.7 MW (5 x 2.125 MVA) Emergency generator: unknown power Main propulsion: 2 x 1.88 MW azimuth thrusters Bow thrusters: 3 x 0.79 MW Stern thrusters: not available

Examples of typical maritime ships

Description of maritime applications

- Compared to the electric propulsion ships, other examples include larger ships, but with diesel/oil based propulsion, so a simpler power network is present and consequently less challenges for protection

LNG carrier

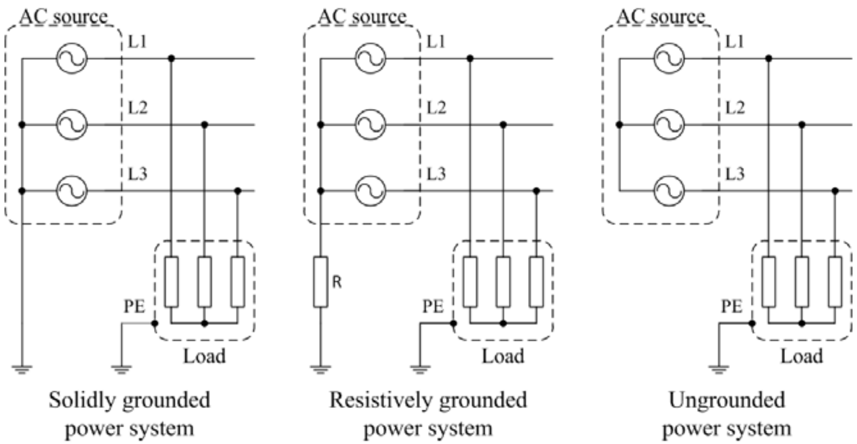
Oil carrier

Container ship

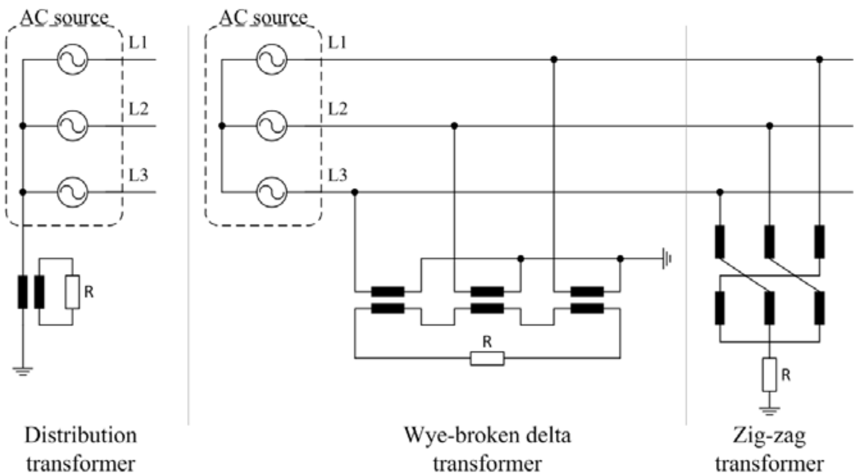
Other examples of maritime ships

Description of maritime applications

- Marine and offshore applications have LV (Low Voltage) and MV (Medium Voltage) power networks:
  - LV (<1 kV) part of the power system is typically ungrounded (however, capacitive coupling is present)
  - MV (>1 kV) part of the power system is typically grounded (solidly, resistively or through grounding transformers)



Power system grounding (3-phase, 3-wire)

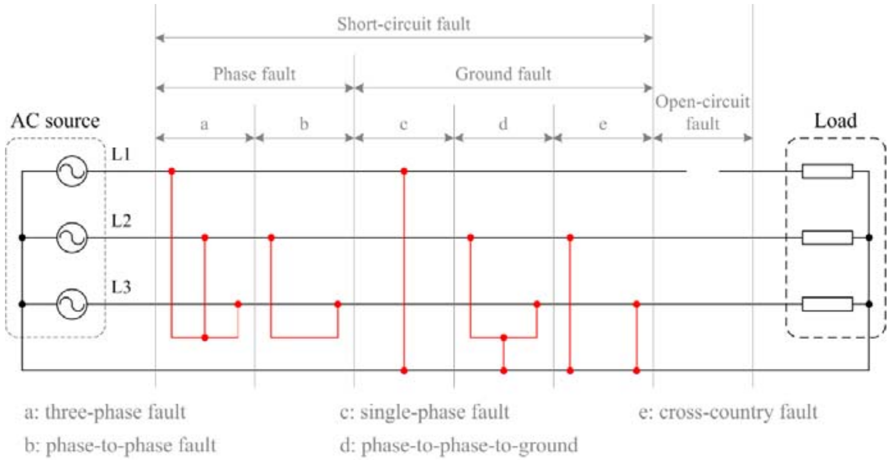


Grounding transformers

Description of maritime applications

The following types of fault may occur in any power system, including the maritime applications:

- open-circuit faults
- short-circuit faults
  - phase faults
  - ground faults
- other abnormal conditions
  - inter-turn faults
  - overloading
  - active power deficit
  - under-excitation
  - over-fluxing
  - loss of synchronism
  - mechanical defects



Basic electrical faults in 3-phase power systems

- Description of maritime applications
- **Specific challenges in maritime sector**
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Specific challenges in maritime sector

- An electric fault can be extremely dangerous in maritime sector (marine & offshore applications), as the following situations may occur: risk of fire, power blackouts, loss of propulsion, shock hazard, …

- Several protection strategies are applied in the maritime sector, but new solutions are needed to cope with the continuous increasing complexity of the new applications that challenge the protection system

- It is important that the protection system operates fast and isolates the affected part of the network during the abnormal conditions, so that electric fault is cleared before its unwanted effects are produced

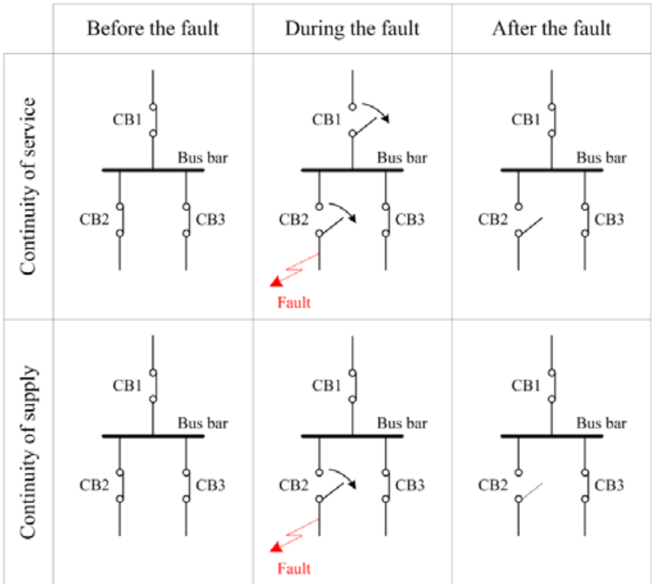
- A maritime protection system also needs to comply with the requirements of the classification society that accredited the vessel

Specific challenges in maritime sector

- Maritime applications need to meet the "survivability" condition, defined as the *continuous operation* of the essential equipment regardless of the system status (including faulted or abnormal conditions)

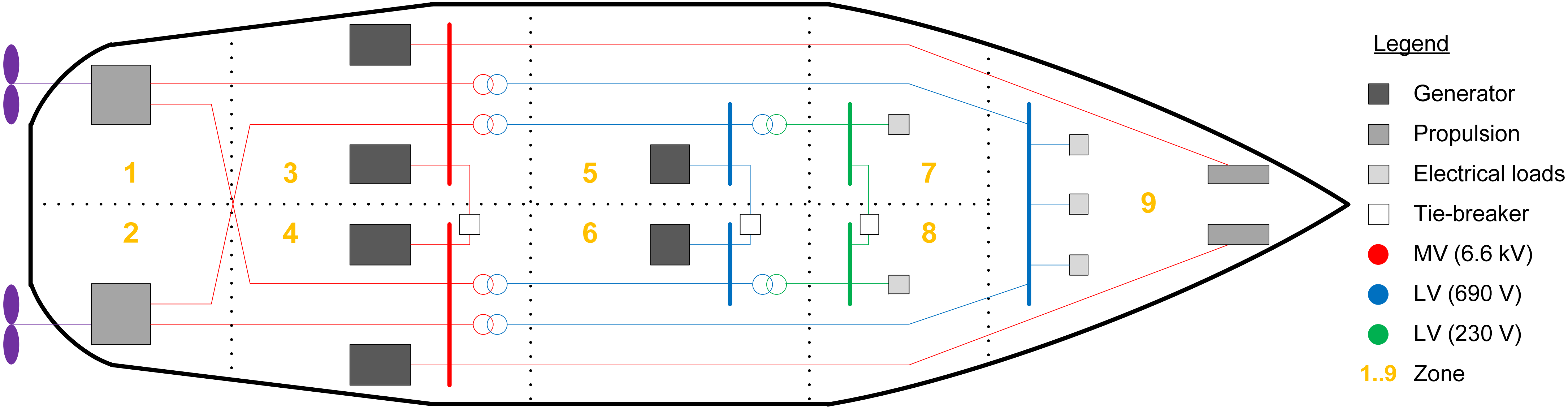
- There are 2 aspects of the *continuous operation* concept:
  - continuity of service
  - continuity of supply

- Survivability condition is achieved by:
  - zonal ship/platform design
  - utilization of several distributed generators
  - flexible architecture of the network



Continuity of operation concept

Specific challenges in maritime sector



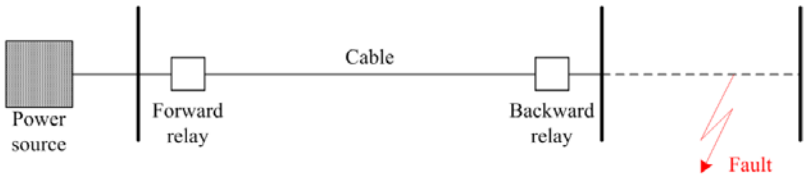
Principle diagram of a marine vessel fulfilling the survivability condition

- Essential equipment is typically represented by propellers, thrusters, cooling devices, pumps, cranes, …

Specific challenges in maritime sector

- The new maritime applications introduce higher generation/load levels, variable generation/load profiles, higher voltage levels, power electronics based consumers and more complex power networks

- Among the issues that characterize the power system protection of a marine or offshore application are:
  - low short-circuit power and current – affects the forward relay settings
  - variable generation and load profiles – affects the backward relay settings
  - reconfiguration of the network – changes the short-circuit current seen by the protective relays



Single-line diagram of a faulted power system

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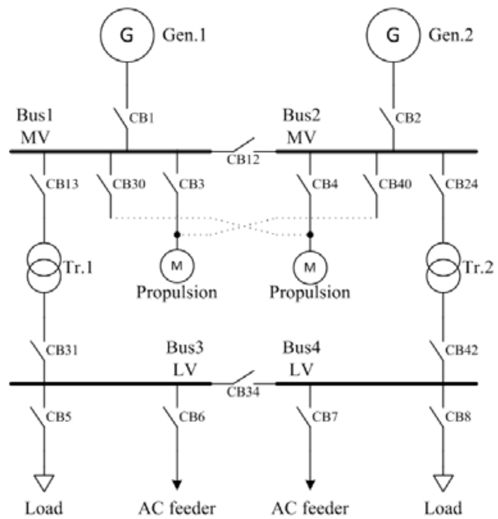
- ❑ **Typical network topologies**
- ❑ Protection principles
- ❑ Conclusion and future work

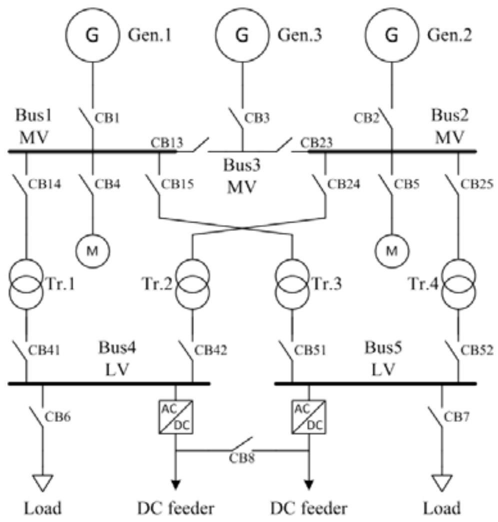
Typical network topologies

- Marine application (diagram 1)
  - 2 generators and 2 MV bus bars (1 tie-breaker)
  - each generator is able to supply the entire network
  - load shedding technique may be applied if needed
  - propulsion can be connected to either of the MV buses
  - LV bus bars powered through 1 transformer or tie-breaker
  - CB12 is normally closed and CB34 is normally open



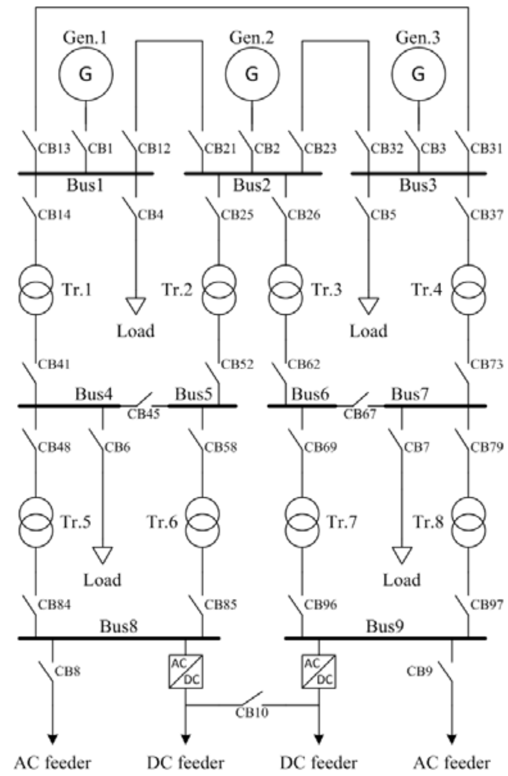
Typical network topologies

- Marine application (diagram 2)
  - 3 generators and 3 MV bus bars (2 tie-breakers)
  - higher flexibility and reliability for the MV network
  - LV bus bars powered from 2 different transformers
  - each transformer connected to the other MV bus bar
  - CB41-CB42 and CB51-CB52 are interlocked
  - CB8 ensures continuity of operation for DC feeders



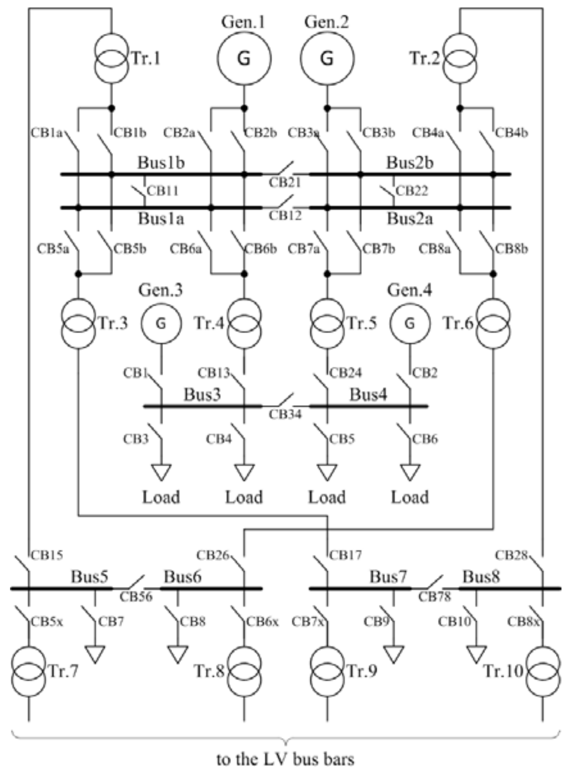
Typical network topologies

- Offshore application (diagram 3)
  - posses some characteristics of the previous diagrams
  - increased complexity, including 2 levels for MV bus bars
  - MV bus bars: level 1 (e.g. 13.8 kV) & level 2 (e.g. 6.9 kV)
  - MV level 1 bus bars (1, 2, 3) form a closed ring
  - MV level 2 bus bars powered through 1 transformer or tie-breaker
  - LV bus bars (8, 9) powered from 2 different transformers



Typical network topologies

- Offshore application (diagram 4)
  - additional features and 3 levels for the MV bus bars
  - level 1 (e.g. 33 kV): main (1a, 2a) and reserve (1b, 2b) bus bars
  - level 2 (e.g. 11 kV) bus bars (3, 4) posses auxiliary generators (3, 4)
  - level 3 (e.g. 6.9 kV) bus bars (5, 6, 7, 8) energize the LV bus bars
  - reverse power flow may occur in some situations
  - resembles the structure and flexibility of a land power station



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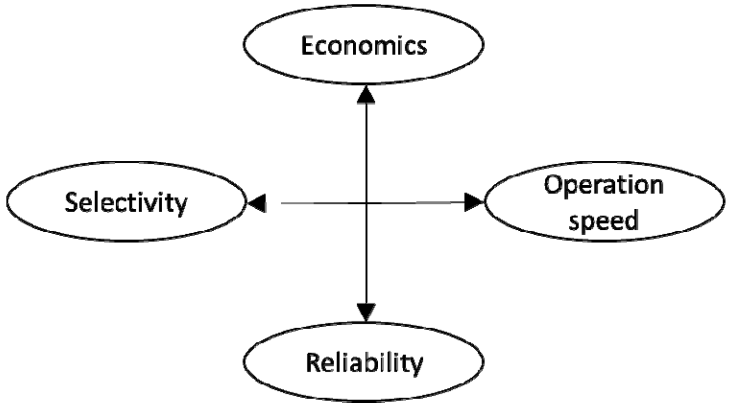
Protection principles

- There is a set of requirements that needs to be fulfilled by the protection system
  - selectivity – only the faulted part of the network is isolated
  - sensitivity – detection of the smallest fault
  - simplicity – as long as the desired functionalities are met
  - operation speed – fault clearance before equipment damage
  - economics – as long as the desired functionalities are met
  - reliability – ability to operate properly, with 2 aspects:
    - dependability – correct operation during fault conditions
    - security – correct operation during normal conditions (assurance of not tripping unless there is a fault)



- Trade-off between the requirements is needed, as no protection system is able to fulfill the entire set

Protection principles

- Due to security reasons, there are 2 levels of protection:
  - primary protection
  - backup (reserve) protection

- Among the protection techniques that are used today in the maritime sector, can be mentioned:
  - protection coordination or discrimination
  - zonal protection principle
  - differential principle
  - directional protection
  - techniques based on symmetrical components
  - other, based on devices as fault locators and insulation monitors
  - ~~distance protection~~

Protection principles

- Considering the maritime challenges and the topologies presented before, it is suggested that the protection system needs to be *adaptive* to the network reconfiguration and operation status

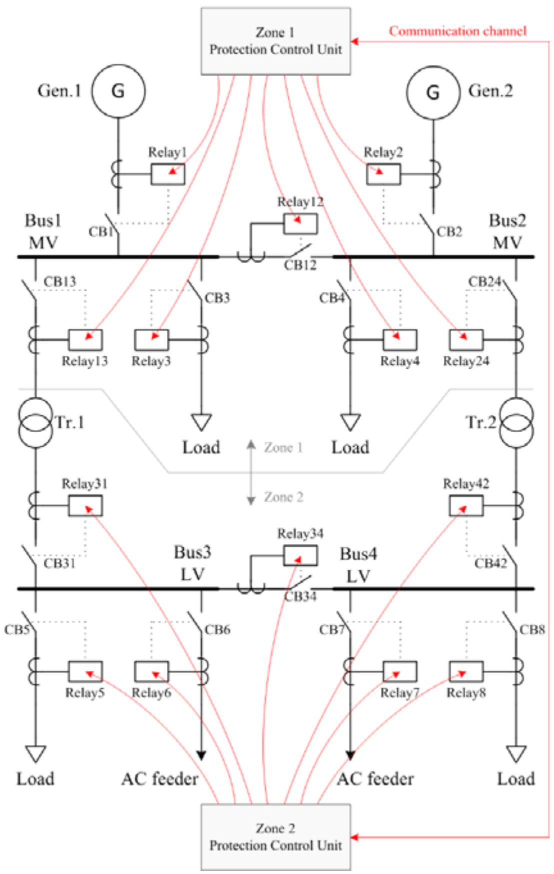
- Similar problems as in the maritime sector are found in the land based MV networks due to the increased penetration level of the distributed generation and adaptive protection is the technical solution to them

- It implies the existence of a central control unit, but the zonal ship design suggests that such approach should be avoided in order to meet the survivability condition, thus a new implementation is needed

- As result, a *decentralized* adaptive protection system could be proposed in maritime applications

Protection principles

- A possible version of decentralized adaptive protection
  - applied to the diagram 1 (marine application)
  - power network in divided in 2 zones
  - a Protection Control Unit for each zone
  - monitoring is realized by CTs, VTs and CB status indicators
  - communication channel allows zonal data exchange
  - same principle is applied to more complex power networks



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Conclusion and future work

- A set of specific requirements and technical challenges need to be fulfilled by a protection system in order to be compatible with the marine and offshore applications

- Protection system needs to be flexible, so it can be applied to a wide range of network topologies

- A new protection method that offers similar functionalities as the adaptive protection, but using a decentralized control intelligence is adequate to respond to the needs of the maritime sector

- Future work is going to address the problem and to investigate implementation of the adaptive protection in marine and offshore applications, according to the principles presented today

Thank you!